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Search for Pentaquark in Low Energy Kaon Beam

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Pentaquark Search at E949

- Resonance formation reaction

  $K^+ n \rightarrow K_S{}^0 p \rightarrow \pi^+\pi^- p$

  -$P(K^+)$=440 MeV/c

  -neutron in Sci. Tgt.

- $\pi^+\pi^- p$ detection

  at UTC (and others?)

  $M(\pi^+\pi^-)=M(K_S{}^0)$

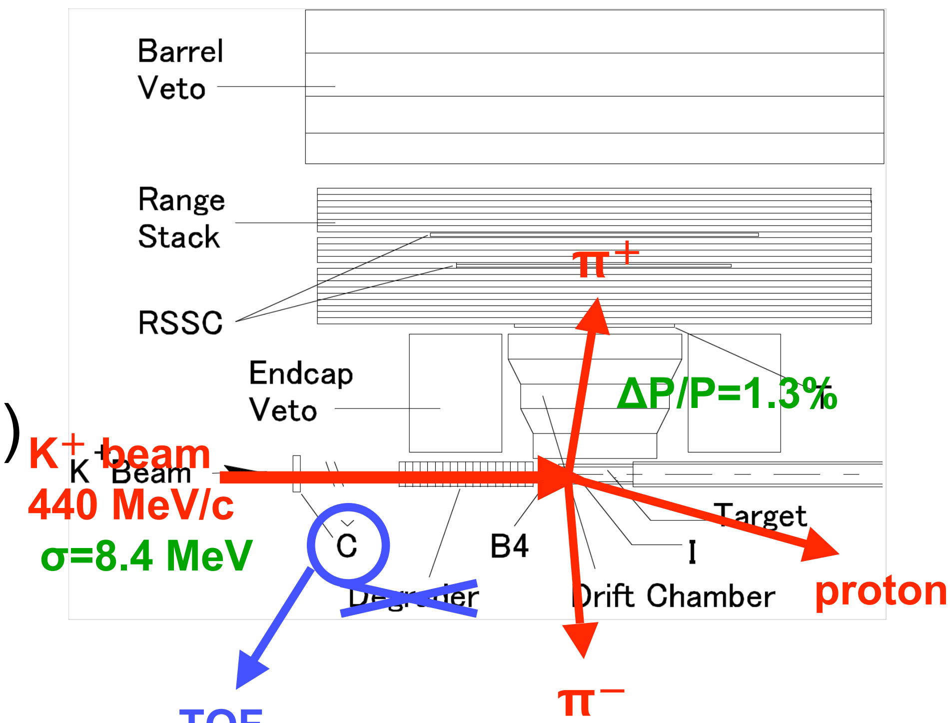
  $\Rightarrow M(K_S{}^0 p)=M(\Theta^+)$

- $\pi^+\pi^-$ detection at UTC

  $M(\pi^+\pi^-)=M(K_S{}^0)$

  $MM(K^+,\pi^+\pi^-)=M(p)$

  $\Rightarrow M(K^+n)$ with Fermi-correction



Δv/v=Δt/t, v=L/t, Δt=200 psec

⇒ L=4 m is equivalent to σ=8.4 MeV

K/π separation : ~6 nsec

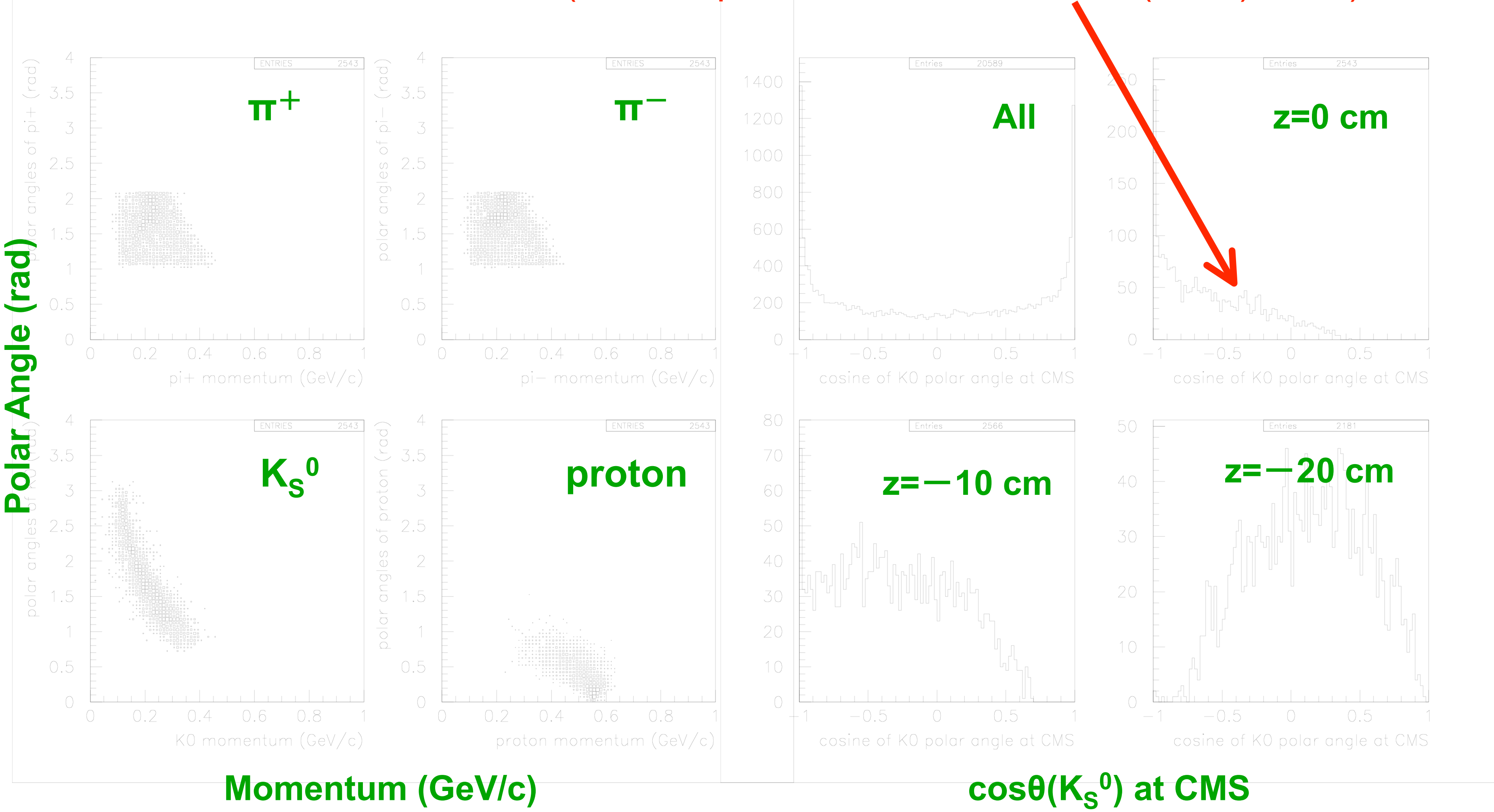
Toy MC simulation

- 440 MeV/c K^+ beam in z-direction
- Fermi motion of neutron inside carbon by harmonic oscillator model.
- Breit-Wigner resonance

  $M=1540$ MeV and $\Gamma=10$ MeV
- Flat generation of K_S^0 and proton at CMS
- Flat generation of π^+ and π^- at K_S^0 rest frame
- Lorentz transformation to Lab frame

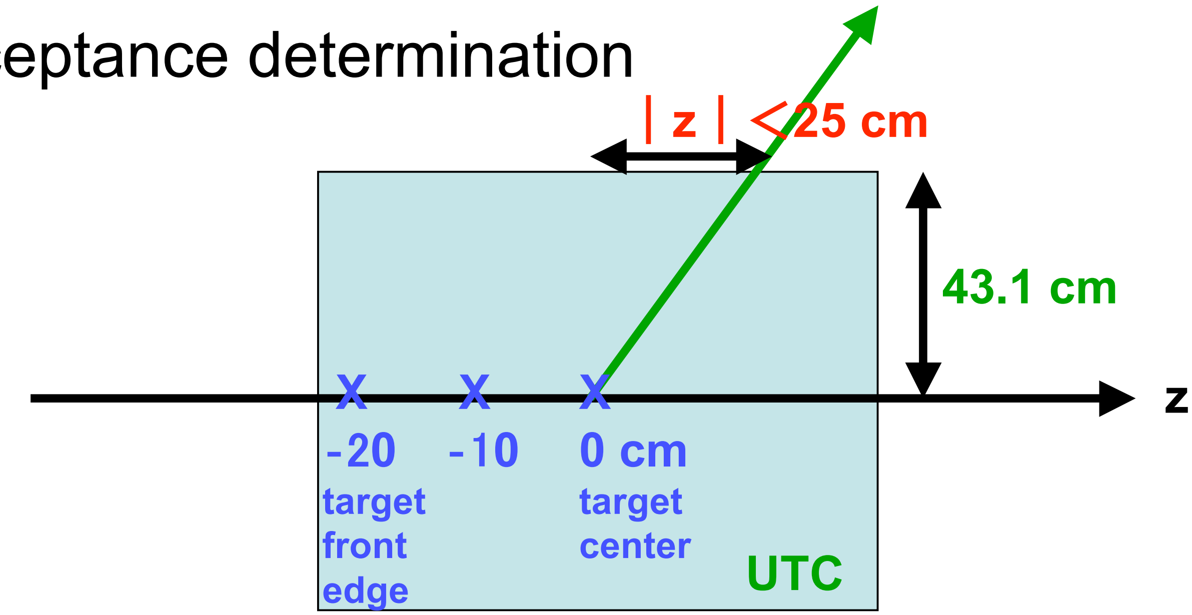
Kinematics in $\pi^+\pi^-$ detection mode

Backward production at CMS (26 mb for Γ=1 MeV)
vs.
CEX BG (forward peaked, 7 mb in PRD15 (1977) 1846)



Experimental Considerations

- Acceptance determination



- CMS energy resolution for mass measurement

  M(K^+ and rest neutron) with Fermi corr. − true E_{CMS}

  ⇒ Validity check of Fermi corr.

- See initial works at http://www.phy.bnl.gov/e949/analysis/pentaquark

Geometrical Acceptance Measurement

- In case that $\pi^+\pi^-$ or $\pi^+\pi^-p$ are detected at UTC

	two pions (K_S^0)	two pions + proton
z= 0 cm	0.1235±0.0023	0.0006±0.0002
-10 cm	0.1242±0.0023	0.0182±0.0009
-20 cm	0.1056±0.0021	0.0602±0.0017

- In case that $P(K^+)$ resolution = 8.4 MeV, UTC resolution = 1.3% and RMS of beam dist. = 4 cm

	two pions (K_S^0)	two pions + proton
z= 0 cm	0.1282±0.0023	0.0003±0.0001
-10 cm	0.1192±0.0023	0.0180±0.0009
-20 cm	0.1062±0.0021	0.0616±0.0017

⇒ No big change in the realistic case

Acceptances with proton detection

- In case proton is detected at inner two layers of UTC.

  | z-position at r=30 cm | < 25 cm is assumed.

  $P(K^+)$ resolution, UTC resolution and beam dist. are included.

	two pions + proton	
z= 0 cm	0.0045±0.0005	
-10 cm	0.0427±0.0014	
-20 cm	0.0831±0.0019	Not so enhanced

- In case that proton Is detected at sci. target.

  θ_{proton} < 0.3 rad by assuming R_{proton} ~ 20 cm

	two pions + proton	
z= 0 cm	0.0436±0.0004	How about resolution?
-10 cm	0.0177±0.0009	
-20 cm	0.0013±0.0003	

- Range counter instead of End-Cap?

Fermi Correction

- Analytical Formula

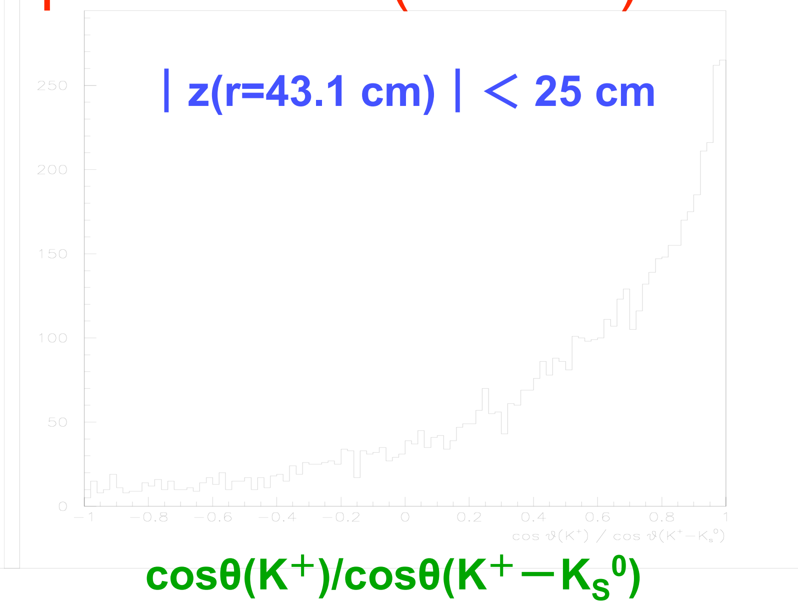
$$\left[M^{C}(K^{+}n)\right]^{2}=\left[M(K^{+}n)\right]^{2}-\frac{\left|P_{K^{+}}\right|}{\left|P_{K^{+}}-P_{K_{S}^{0}}\right|}\times\left\{\left[MM(K^{+},\pi^{+}\pi^{-})\right]^{2}-\left[M_{p}\right]^{2}\right\}$$

- But some approximations…

  $E_f=M_n+P_f^2/(2M_n)$ and neglect P_f^2 terms

  $\cos\theta(K^+)/\cos\theta(K^+-K_S^0)=1$

  $\Rightarrow$ Valid for backward K_S^0 productions (z=0 cm)



CMS energy resolution

- No beam & detector resolutions

	All fitting range	−0.015~0.015
	11.11±0.12	8.31±0.12 MeV

- Changing beam res. with UTC res. 1.3%

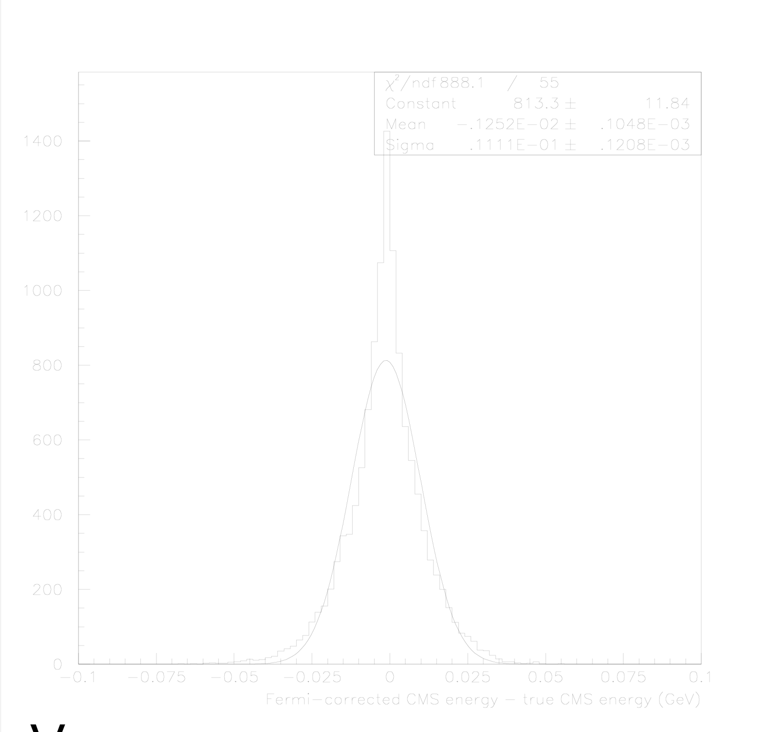
8.4 MeV	11.61±0.12	8.74±0.12 MeV
20 MeV	12.91±0.11	10.94±0.21 MeV
30 MeV	14.26±0.11	12.31±0.29 MeV
40 MeV	15.77±0.11	14.28±0.45 MeV
50 MeV	17.62±0.12	17.11±0.78 MeV

- Changing UTC res. with beam res. 8.4 MeV

1.3%	11.61±0.12	8.74±0.12	5.07±0.17 MeV
3.0%	13.00±0.12	10.31±0.18	10.79±0.46 MeV
4.5%	14.91±0.13	12.45±0.31	15.65±0.83 MeV
6.0%	17.29±0.15	14.80±0.51	22.88±1.35 MeV

- 10 MeV resolution is retained in the realistic case

$\pi^+\pi^-p$ detection at UTC



Beam Momentum Setting

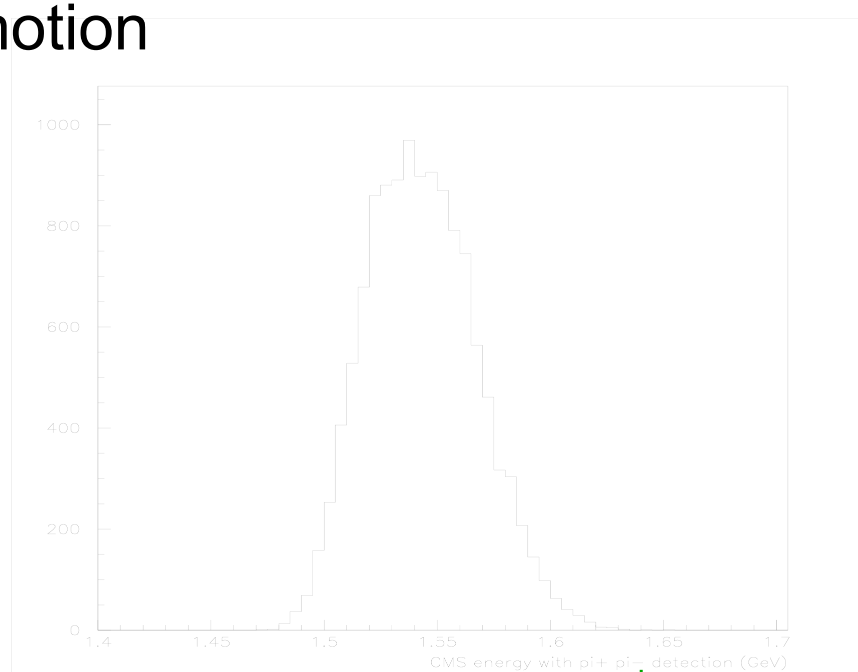
- $P(K^+)$=442 MeV/c for $M(\Theta^+)$=1.540 GeV

  but

  $P(K^+)$=417 MeV/c for $M(\Theta^+)$=1.530 GeV (world ave.)
- True CMS energy is spread by ~50 MeV

  because of neutron Fermi motion

Beam Momentum should be
adjusted at ~20 points
in each 10-20 MeV/c



True CMS energy $M(K^+n)$

Summary

- Existence of pentaquark can be confirmed by E949 detector. (There are many null results in high energy experiments.)
- Two pion detection at UTC seems promising.
  (Geometrical acceptance ~10%)
- Two pion + proton detection at UTC may be analyzed
  for z=—20 cm.
- 10 MeV E_{CMS} resolution can be achieved in two pion detection mode with Fermi correction. (Nakano suggested $MM(K^+,\pi^+\pi^-)>0.97$ reduced E_{CMS} res. to 6 MeV with a cost of 80% acc. loss and slight peak shift.) Note that energy resolution with two pions + proton detection is 5 MeV.
- Beam momentum setting: ~20 points in each 10-20 MeV/c.